Spatial Variability of Falling Snow

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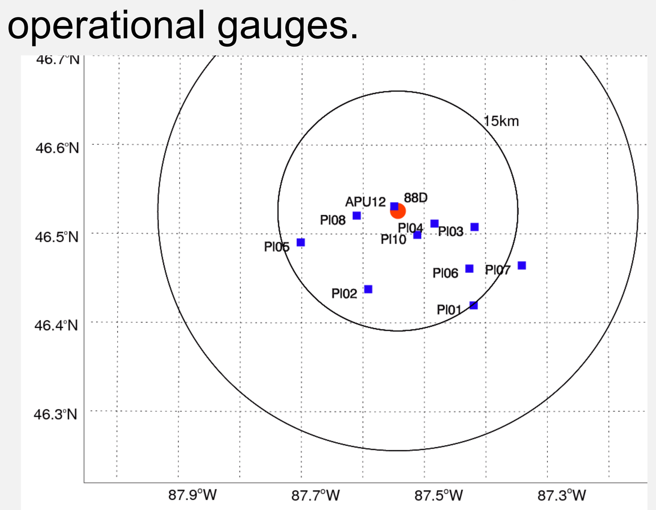
Motivations and Objectives

One of the level-one requirements of the National Aeronautics and Space Administration's Global Precipitation Measurement (GPM) mission is the detection of falling snow within the footprint of GPM Dual-frequency Precipitation Radar (DPR) and instantaneous field of view (IFOV) of GPM Microwave imager (GMI) on board GPM core observatory. The DPR footprint is nearly circular with a diameter of 5 km, while the IFOV of GMI is elliptic and has a range of maximum dimension of 32 km at 10.65 GHz and 7 km at 89 GHz. The non-uniform beam filling within the footprint and IFOV is one of the sources of uncertainty of DPR and GMI-based precipitation estimate.

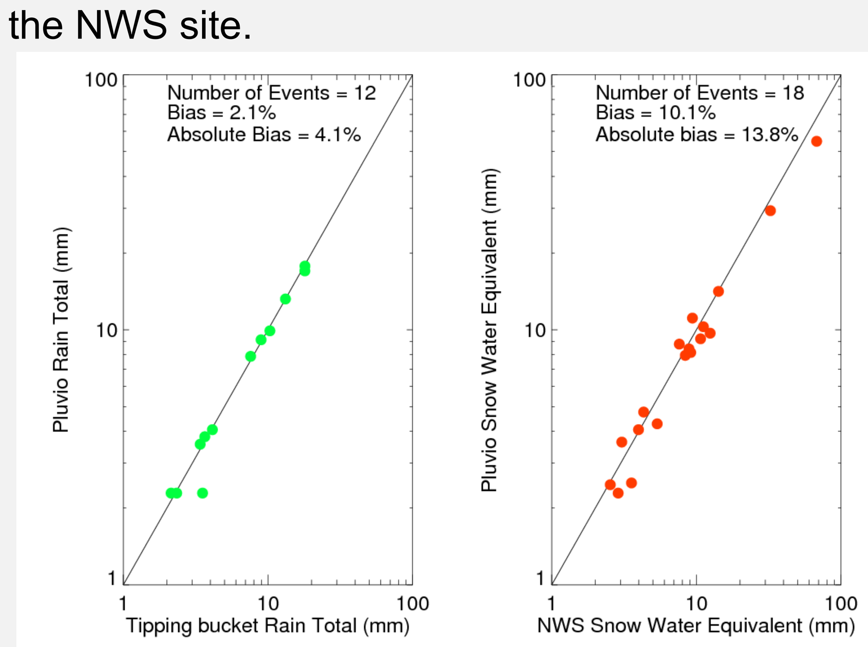
The GPM ground validation is committed to quantify these uncertainties (i.e. spatial variability) utilizing the ground based in-situ and remote sensing sensors. While the spatial variability in rain has been investigated using field-campaign based rain gauge and disdrometer network, there is no study on spatial variability of falling snow. This study is the first attempt to quantify the spatial variability of falling snow by using a network of gauges in Marquette, Michigan.

Sites and Instrumentation

The network of gauges consists of ten Pluvio weighing bucket gauges in Marquette, Michigan illustrated below. The gauges were separated by distances ranging from 2.6 km to 27.8 km and were within 17.5 km of the nearest operational radar (KMQT). One of the gauges was collocated with laser and camera-based optical distrometers, a micro rain radar, and operational gauges.

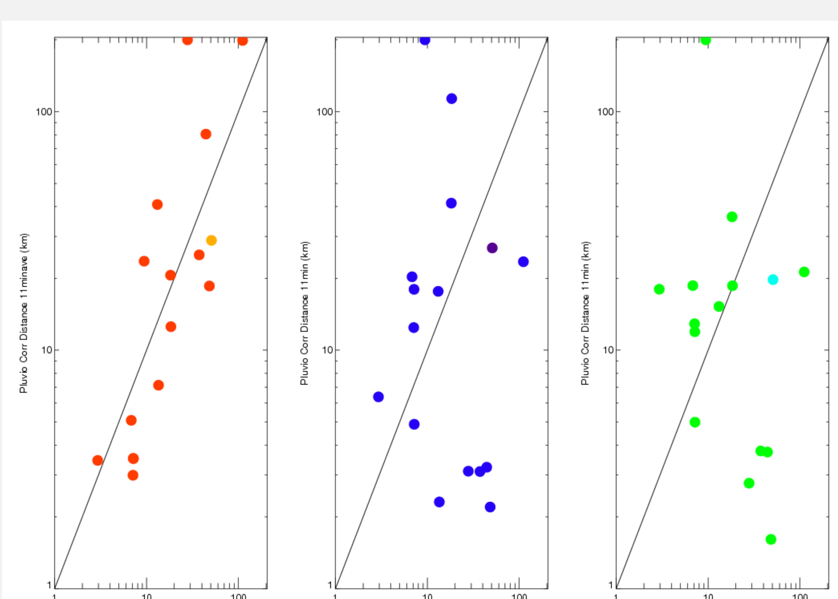


To insure the gauges were working properly, the instruments at the NWS station were compared with one of the Pluvio gauges that was located at the NWS site.



The Pluvio gauge had an excellent agreement with a tipping bucket gauges during rain and a very good agreement with a manual gauge during snow when event rainfall and snowfall totals were compared.

The gauges are designed to measure the snow water equivalent every 10-seconds or a minute, but they were not ideal for short-term accumulations. The gauges occasionally malfunctioned by failing to report snow for 30 minutes to an hour, but eventually outputs the accumulation accurately.



Methodology

Three Parameter Exponential Function:

$$r = r_0 \exp[-\left(\frac{d}{d_o}\right)^s$$

r = correlation, r_0= nugget parameter

d_0= correlation distance, s= shape parameter

d=distance between two gauge sites

Ranges for d_0 and s are 0-300 and 0-2 at increments of 0.1 and 0.01, respectively. The d_0 and s are calculated by minimizing the root mean square error (rmse).

Event Summaries

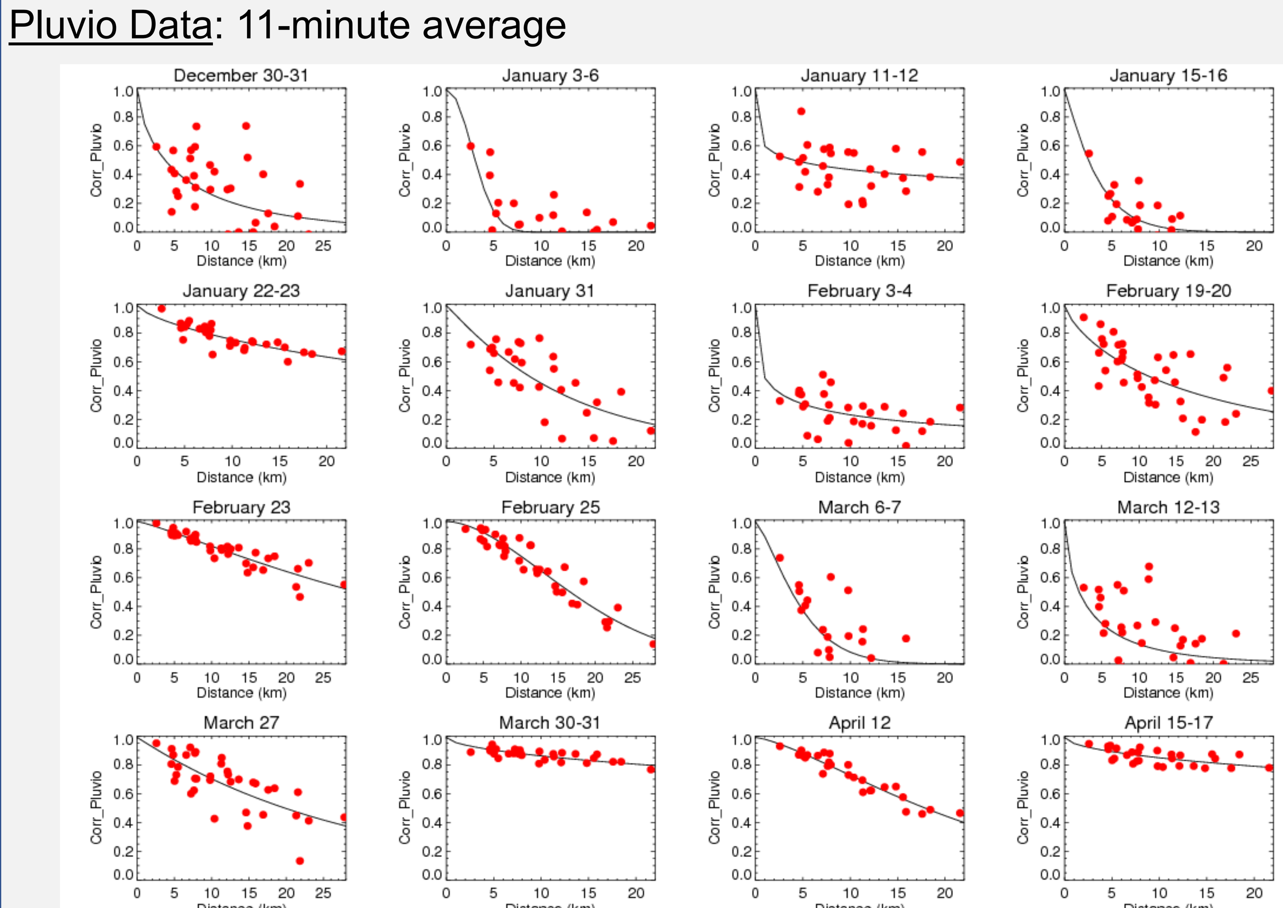
Event Requirements:

1. Precipitation within 12 hours
2. Minimum precipitation total: 2.0 mm
3. Length of event: At least 200 samples of data
4. At least 5 of the gauges reporting precipitation

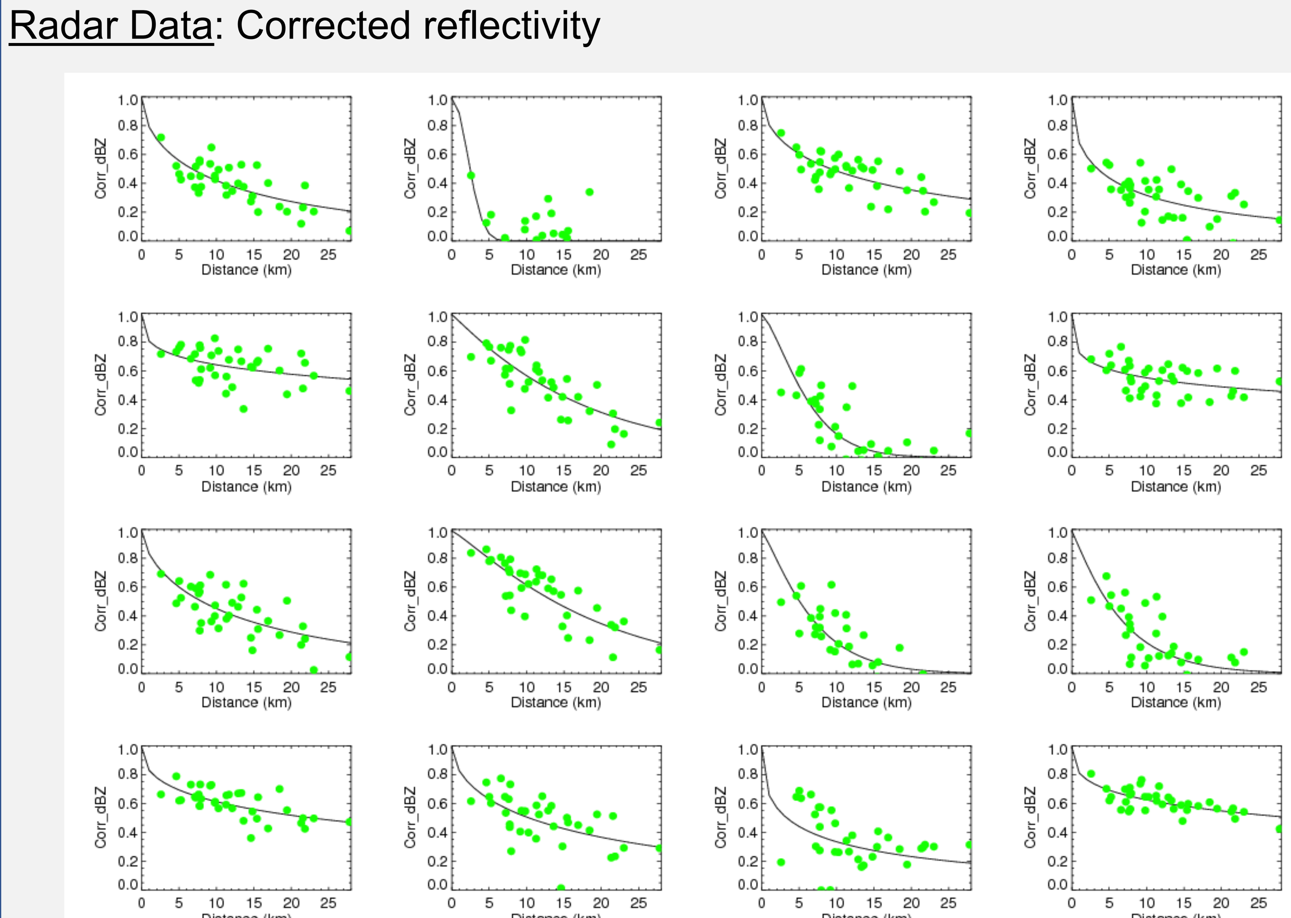
Events (2017-2018)	Avg. Density (g/cm³)	Wet Bulb Temp range (°C)	Storm Type
Dec 30-31	0.049	-17.8 / -11.3	Lake effect
Jan 3-6	0.057	-18.4 / -12.0	Lake effect
Jan 11-12	0.088	-16.0 / 1.5	Lake enhanced
Jan 15-16	0.033	-15.3 / -7.7	Lake effect
Jan 22-23	0.129	-4.4 / -2.4	Synoptic
Jan 31	0.063	-11.1 / -6.3	Lake enhanced
Feb 3-4	0.089	-17.6 / -12.4	Synoptic
Feb 19-20	0.174	-8.2 /-2.5	Synoptic
Feb 23	0.094	-5.9 / -2.5	Synoptic
Feb 25	0.095	-3.3 / -0.1	Synoptic
March 6-7	0.045	-9.4 / -4.6	Synoptic
March 12-13	0.038	-9.5 / -2.1	Lake enhanced
March 27	1.000	-1.1 / 1.2	Rain event
March 30-31	0.071	-10.4 / -4.5	Synoptic
April 12	0.092	-4.4 / 0.0	Synoptic
April 15-17	0.100	-7.6 / -5.0	Synoptic

Spatial Variability

Pluvio Data: 11-minute average



Radar Data: Corrected reflectivity

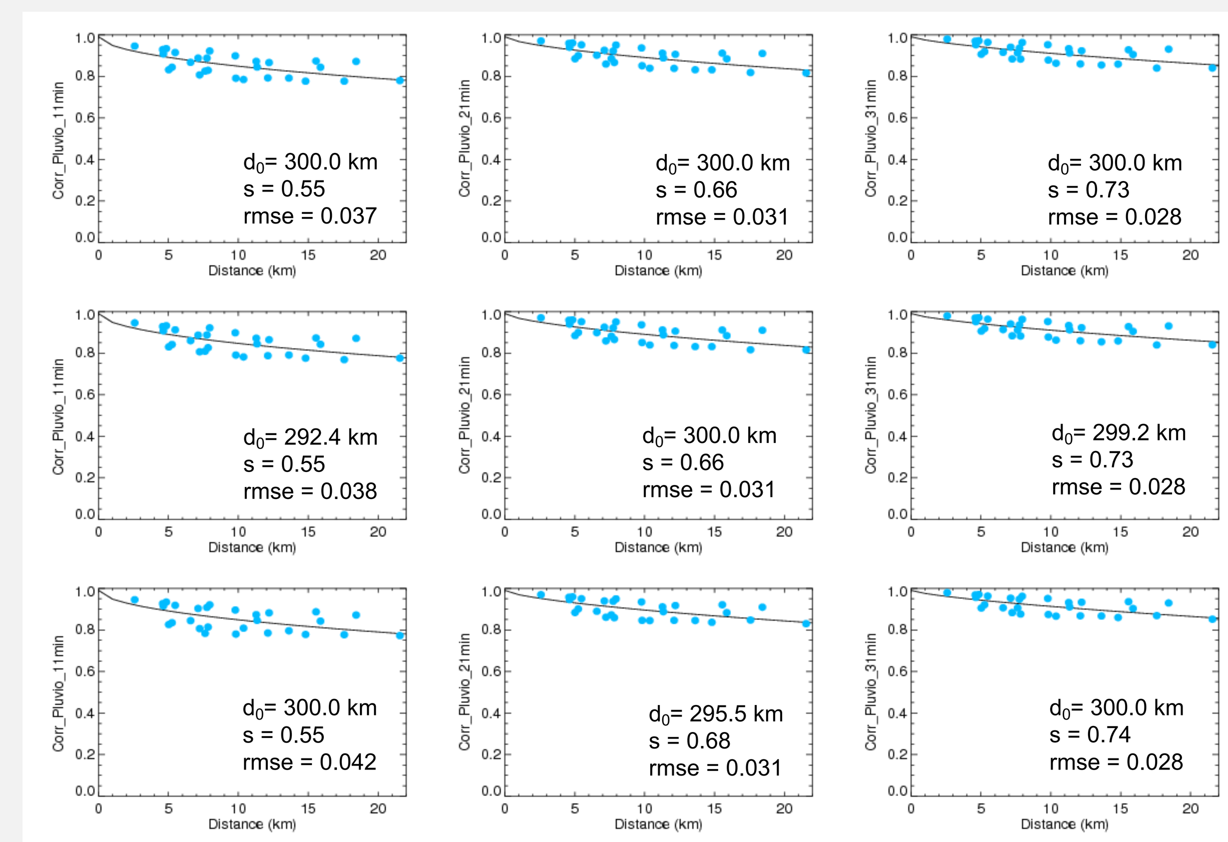


Case Study

The gauge records were accumulated for 11-, 21-, and 31-minute periods centered at the observed minute. Correlations between the paired gauge records were calculated using Pearson's correlation coefficient and the spatial variability was determined using a three parameter exponential function where the correlation at zero distance was assumed to be 0.99. The correlation at a given distance is the input for the exponential fit, while the correlation distance and shape parameters are the outputs.

Synoptic Case:

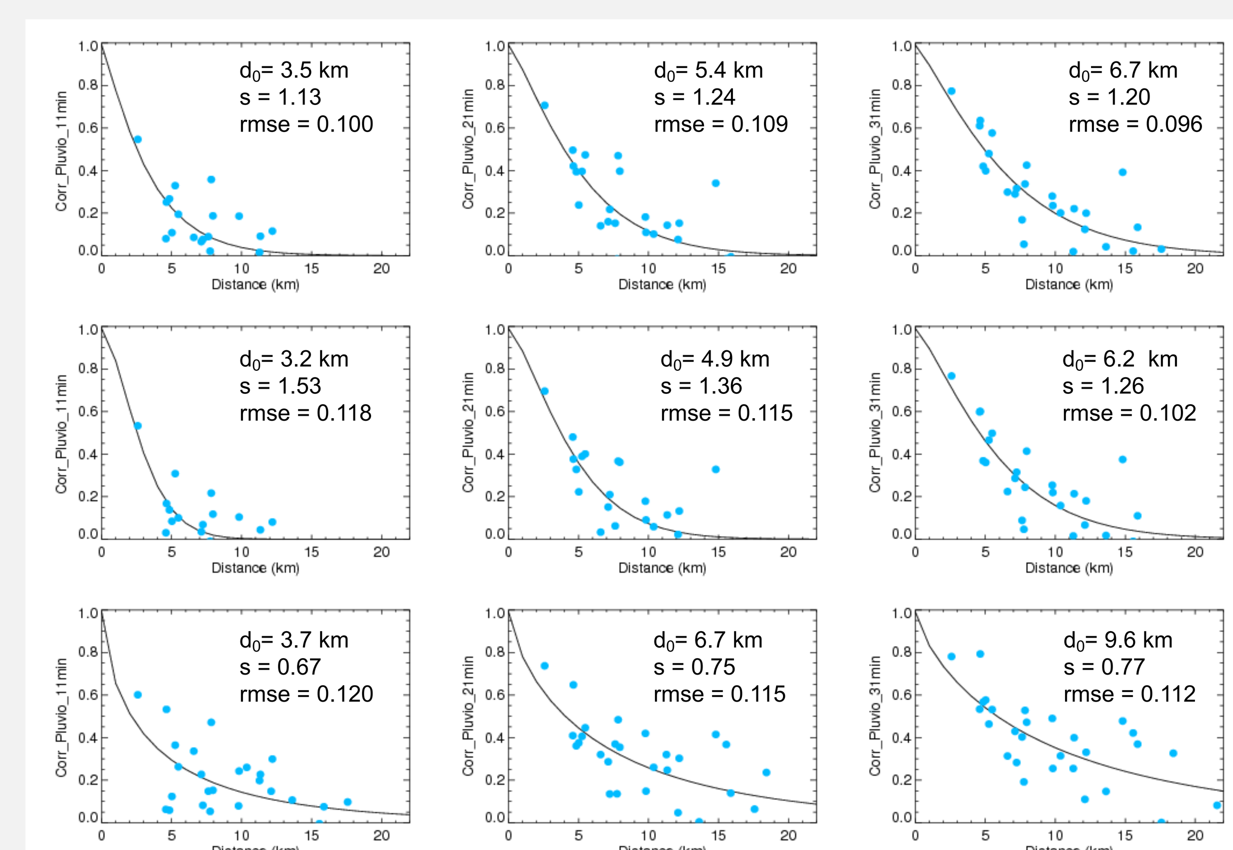
April 15-17



This case illustrates a very highly correlated storm, indicating mostly uniform snow across the region.

Lake Effect Snow Case:

January 15



Above represents a highly variable case. The correlations are extremely low, concluding that the snowfall rates varied drastically in this case.

Conclusions

- Lake-effect snow events appear to have lower correlations, which translates to higher variability, than the snow storms from synoptic systems.
- Higher the snow density, the snowfall rates vary more.

Future Work

- Use the coefficient of variation to determine spatial variability.
- Look at spatial variability at desired locations (simulated gauges) for different IFOV at different GMI frequencies and DPR footprint.

Acknowledgements

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